Cooperative Engagements and Levels of Interoperability (CELI) between Unmanned Aircraft Systems and the AH-64D Longbow

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Executive Summary

Problem Definition The Block III Apache is a modernized version of the currently fielded AH-64D Block II Apache aircraft. The design incorporates technology advancements harvested from other development programs and advances in processing technology since the fielding of the Block I and II AH-64D Apache. One of the major upgrades contained in the Block III Apache configuration is the provision of control systems for Unmanned Aircraft Systems (UAS). UAS with Tactical Common Data Link (TCDL) integration will provide the aircraft crew with capability of level IV control of UASs, allowing the aircraft to control a UAS and immediately relay and receive UAS data.

Concerns have been expressed over the employment and fielding of this new technology by the Apache Block III crew and the UAS team under combat conditions; to include training, education, and communications. This study is helping Army leaders address the issues related to cooperative engagements and levels of interoperability between UAS and AH-64D Apache Longbow aircraft.. Currently, aviators get time-delayed verbal reports of UAS reconnaissance (Level 1 control). Systems exist to provide a real-time payload feed (Level 2). The Army program managers for UAS and for Apache helicopters are interested in whether it will be beneficial to provide actual control of the payload (Level 3) or control of the unmanned aerial vehicle itself (Level 4) to an aviator in his or her cockpit. There are a variety of individuals and organizations that have a vested interest in this problem and its solution.

Technical Approach The approach consisted of three integrated efforts:

1. Experimentation with rated AH-64D helicopter pilots in the Risk Assessment Cost Reduction Simulator (RACRS) to determine the value and change in crew workload due to Video from Unmanned air systems for Interoperability Teaming Level II (VUIT-2), a system currently being installed in Block II Apache Aircraft.

2. Experimentation using a lower resolution game-based simulation, Virtual Battlespace 2 (VBS2), to provide insight as to whether this type of environment can represent and validate experimentation conducted in a much higher resolution and more expensive environment such as the RACRS. Through subjective and objective measures this experiment was designed to identify whether there are significant differences in a pilots performance, workload, and situational awareness between level I and level II interoperability with a UAS.

3. Using fundamental systems analysis techniques such as stakeholder and functional analysis combined with Human Factors and Accident Classification and risk management techniques develop a prioritized list of recommended controls to reduce the risk of mission failure during cooperative engagements between manned and unmanned aircraft systems.

Results 1. During experimentation in the RACRS, with no statistically significant increase in workload, pilots reported that

a.   It was easier for to detect and engage targets using the VUIT-2 due to the steep visual aspect angle compared to the Target Acquisition Designation Sight (TADS)

b.   Situation awareness provided by the VUIT-2 reduced the time required to detect and engage targets

c.   There were more tasks to complete, due to the additional sensor, but there was more time to complete target detection and engagement tasks because of the greater stand-off range.

d.   During the entire experiment the Bedford workload ratings elicited through surveys and subject matter experts stayed well below the threshold established in the Apache Block III capability development document (CDD).

2. The low resolution experiment enabled the analysts to reject the null hypothesis that there was no difference in the mean response for performance, workload, and situational awareness. Factors in all three areas indicated improvements in those areas, basically the same results that were found in the higher resolution environment in the RACRS.

3. A Prioritized list of recommendations and considerations concerning cooperative engagements was provided to the client. Controls address all elements of doctrine, organization, training, materiel, logistics, personnel, and facilities (DOTMLPF) and identified opportunities to reduce the risk of mission failure.

The client expressed interest in sharing these findings with Department of Defense (DoD) Aviation leadership and directed that two of the recommendations be pursued immediately; he encouraged a continued relationship with West Point and the program managers for Apache and UAS. The two recommendations that will be immediately addressed are:

a.   The development of an Army virtual training system similar to the Marines' Deployable Virtual Training Environment (DVTE). This will address a training gap at the individual, team, and unit levels, and will lead to improved RACRS, Longbow Crew Trainer (LCT), and BDE TOC simulation capabilities.

b.   Development of a Cooperative engagements leaders training guide to provide essential information to commanders and staffs regarding manned/unmanned cooperative engagements in the operational environment. This handbook is intended to be a quick-reference for military commanders at Brigade-level and below to employ this unique asset.

Contents

1 Introduction

This study outlines efforts by the Operations Research Center, in the West Point Department of Systems Engineering, to look into some of the considerations for integrating UAS video into the Apache cockpit in order to support cooperative engagements between UAS and attack helicopters. In these cooperative engagements, the UAS initially detects the target. A tactical operations center then does coordination with pre-planned or dynamically re-tasked aviation assets to move to the target area and engage the target. As the UAS hands off the target, the ability to view the UAS video inside the Apache cockpit supports a faster and more reliable target acquisition with greater situation awareness of the target area. This study addresses concerns about the cognitive workload this additional video places on the pilots. It also addresses some of the factors associated with overall success of cooperative engagements. This second portion of the study included a deployment into Iraq and Afghanistan to do detailed stakeholder analysis and functional analysis in order to better understand cooperative engagements and the potential challenges they pose for all elements of this systems of systems integration.

1.1 System Description

Specifically, this study addresses the system of systems integration between the Apache helicopter and Army UAS using the VUIT-2 interface.

1.1.1 The Block III Apache

The Block III Apache is a modernized version of the currently fielded AH-64D Block II Apache aircraft. The design incorporates technology advancements harvested from other development programs and advances in processing technology since the fielding of the Block I and II AH-64D Apache (Figure 1). The planned upgrades will result in improved aircraft performance, reduced operating costs, and improved mission performance.

Fig. 1: AH-64D Apache Aircraft

The backbone of the upgrade package is the replacement of obsolescent processing hardware with updated Mission Processors (MP) and Aircraft Interface Units (AIU). This modernized processing capability supports several new and enhanced system upgrades.

One of the major upgrades contained in the Block III Apache configuration is the provision of control systems for Unmanned Aircraft Systems (UAS). UAS with Tactical Common Data Link (TCDL) integration will provide the aircraft crew with capability of level IV control of UASs, allowing the aircraft to control a UAS and immediately relay and receive UAS data.

1.1.2 Unmanned Aircraft Systems

UAS operations support battlefield commanders and their staffs as they plan, coordinate, and execute operations. UAS increase the situational awareness (SA) of commanders through intelligence, surveillance, and reconnaissance (ISR). Armed UAS provide commanders direct fire capabilities to prosecute the close fight and influence shaping of the battlefield. Army UAS can perform some or all of the following functions: enhanced targeting through acquisition, detection, designation, suppression and destruction of enemy targets, and battle damage assessment (BDA). Other UAS missions support the maneuver

1

commander by contributing to the effective tactical operations of smaller units. Ground Control Stations (GCS) with common data links, remote video terminals (RVTs) and remote operations video enhanced receiver (ROVER), portable ground control stations (PGCSs), and Army helicopter/Army airborne command and control system (A2C2S)/UAS teaming will enhance SA and the common operational picture (COP), helping to set the conditions for operational success (FM 3-04.155, 2006).

There are three classes of UAS: man-portable, tactical, and theater. The four different types of UAS the Army uses to conduct operations are:

- Improved–Gnat (I-Gnat) (RQ-1L).
- Hunter (RQ-5/MQ-5).
- Shadow (RQ-7).
- Raven (RQ-11).

Although all UAS capabilities were considered during this study the primary UAS was the tactical UAS (TUAS) Shadow based on its mission, capabilities and current use and integration in Brigade Combat Team (BCT) operations deployed in OEF and OIF (Figure 2) (Department of Defense, 2007).

The Shadow 200 is a small, lightweight TUAS designed as a ground maneuver commander's primary day or night reconnaissance, surveillance, target acquisition system. The Shadow 200 employment is flexible and can be tailored to support operations down to company or squad level. The TUAS also greatly enhances force protection with its on station loitering ability and high-resolution sensors. As a command and control enabler for tactical decision making, it's the commander's "dominant eye", allowing him to shape the battlefield to ensure mission success.

1.1.3   VUIT-2

The Video from UAS for Interoperability Teaming Level II (VUIT-2) system is designed to enhance interoperability between the UAS and the AH-64D. This is accomplished by providing (real time)

Fig. 2: Launching the Shadow UAV

streaming video from a UAS sensor to the AH-64D crew and allowing the crew to re-transmit that video or "ownship" target acquisition designation sight/modified-target acquisition designation sight (TADS/M-TADS) video to a ground unit equipped with a man-portable one system-remote video terminal (OSRVT) or to another airborne OSRVT. The flow of information between the UAS, AH- 64D, and OSRVT is depicted in Figure 3 (Hicks et al., 2008).

The major components of the VUIT-2 system on the AH- 64D are: a mast-mounted C/L-band omnidirectional antenna for reception of UAS video and an ultra high frequency (UHF) antenna for reception of UAS metadata; an OSRVT and Thermite computer to process received video for presentation on the crew member selected multipurpose display (MPD) (Figure 4); keyboard style control that permits the copilot gunner (CPG) to interface with the VUIT-2 system; a mini-tactical common data link (MTCDL) system that permits transmission of received UAS or "ownship" TADS/M-TADS video to a ground or airborne OSRVT. The VUIT-2 is incorporated as a strap-on system for Block I and II AH-64Ds involving minimal interface with the current production aircraft bus architecture. The video signal generated by the Thermite computer shares the line-out of the aircraft video playback system between the recorder and the
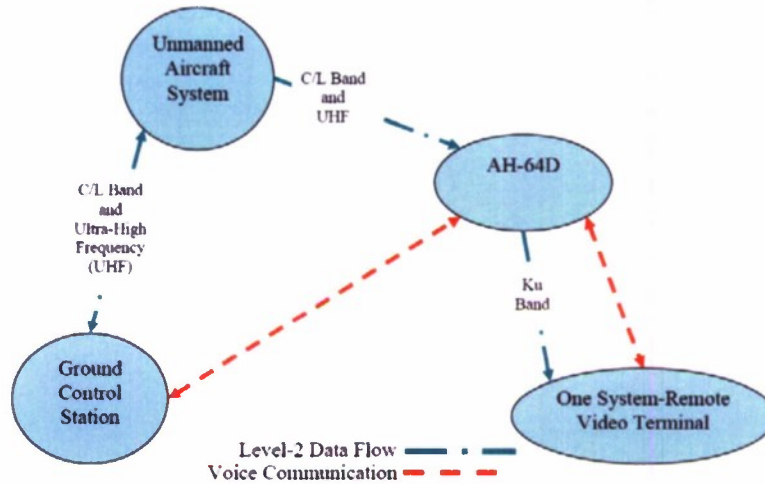
Fig. 3: VUIT-2 information flow.

MPD requiring the aircraft video recorder to be in playback mode to view UAS video.

1.1.4 System of Systems

There are a number of definitions of a system of systems, for example:

> "... an integrated force package of interoperable systems acting as a single system to achieve a mission capability. Typical characteristics include a high degree of collaboration and coordination, flexible addition or removal of component systems, and a net-centric architecture..." (Assistant Secretary of the Navy for Research, Development, and Acquisition, 2006)
>
> "... a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities..." (dod, 2004)
>
> "[Systems] of systems exist when there is a presence of a majority of the following

five characteristics: operational and managerial independence, geographical distribution, emergent behavior, and evolutionary development." (Sage and Cuppan, 2001)

The system of systems identified for this research effort depicts a system boundary around the interactions between a UAS and AH-64D during a cooperative engagement, Figure 5.

Regardless of the definition used, the characteristics of a cooperative engagement between manned and unmanned systems lead the analyst to conclude that it is a system of systems:

- Air space management and safety achieved by all component systems working together

- Individual systems provide useful services (fire power, real time video)

- Individual systems are acquired independently with different contractors

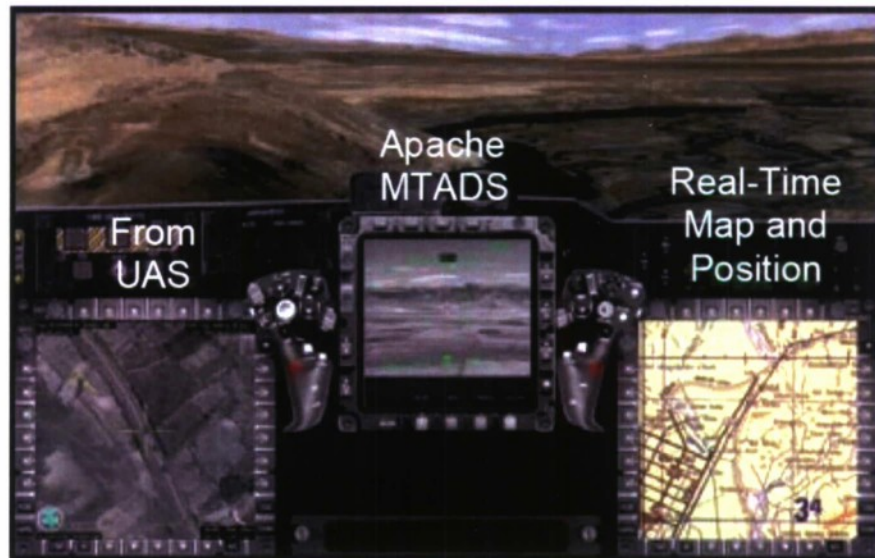- Individual systems come and go routinely

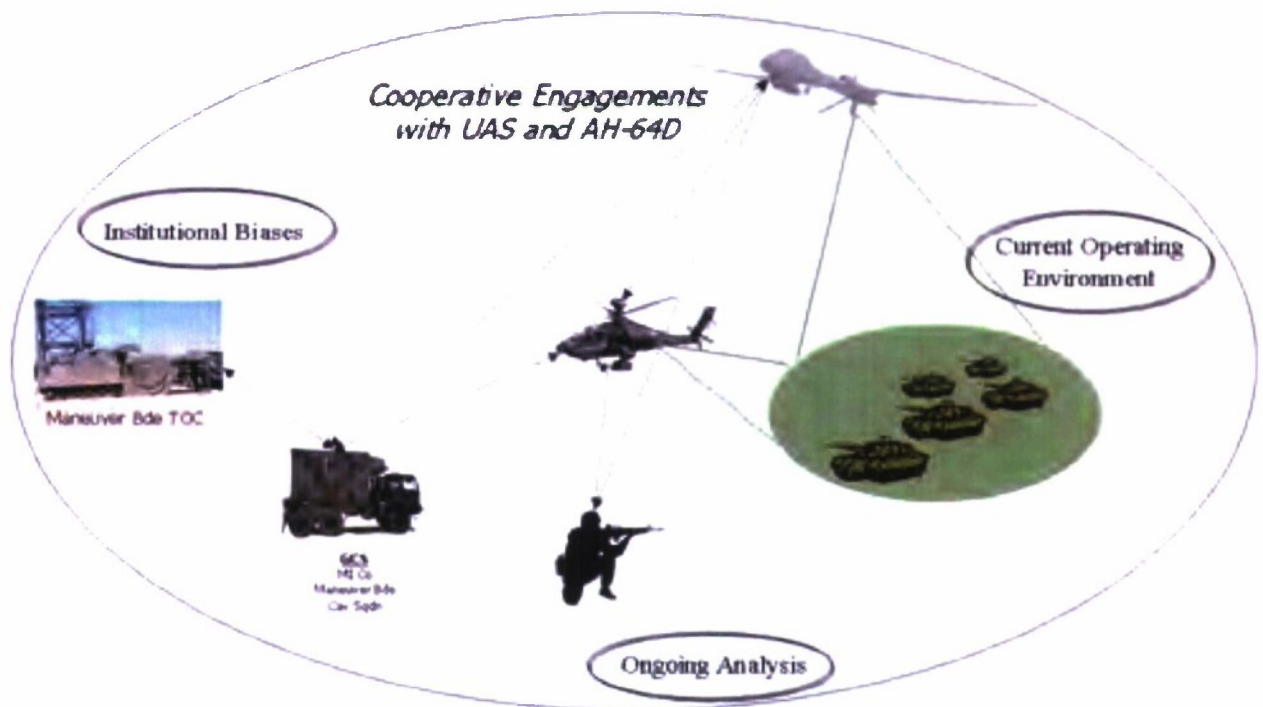- Highly network centric

Fig. 4: VUIT-2 layout.

Fig. 5: Cooperative engagements system of systems.

	Level I	Level II	Level III	Level IV	Level V
Launch & Recovery				■	■
Flight Maneuver				■	■
Payload Control			■	■	■
Direct Data Receipt		■	■	■	■
Secondary Products	■	■	■	■	■

Fig. 6: Levels of interoperability.

- Standard protocols and interfaces

- Geographically dispersed

- System complexity leads to emergent behavior

- Extensive coordination is central to achieving high levels of efficiency and safety

Although these characteristics provide great capability to the system, they also expose the system to high risk vulnerabilities that must be addressed.

1.2   Problem

Concerns have been expressed over the employment and fielding of the technology that would provide an AH-64D crew different levels of interoperability (sometimes referred to as levels of control); to include issues surrounding training, education, and communications between the manned and unmanned crews. The interaction between these crews is referred to as cooperative engagements; during these engagements the crews will experience different levels of interoperability (Figure 6). Currently, aviators get time-delayed verbal reports of UAS reconnaissance (Level 1 control). Systems exist to provide a real-time payload feed, or live video (Level 2). The Block III Longbow will have integrated capabilities for the crew to obtain actual control of the payload (Level 3) or control of the unmanned aerial vehicle itself (Level 4). There are a variety of individuals and organizations that have a vested interest in this problem and its solution. This research will not address Level V control.

2   Background

In October 2000, the Training and Doctrine Command (TRADOC) System Manager (TSM), now designated as the TRADOC Capabilities Manager (TCM) explored the volumes of UAS analyses that had been conducted over the years.

- Army Aviation Unmanned Aerial Vehicle Study (1993)

- Assessment Of Non-Lethal Unmanned Aerial Vehicle Integration with Combat Aviation Missions Study (1994)

- Birddog Advanced Technology Demonstration (ATD) (1995)

- Global Wargame '96/97 (1996/1997)

- Boeing Manned/Unmanned Teaming Concept (1997)

- Manned and Unmanned Aerial Platform Operations on the Digitized Battlefield (MUM I) Concept Experimentation Program (CEP) (1997)

- Analysis Of Comanche Helicopter – Its Contribution As An Aerial Armed Reconnaissance Platform Study (Vector Research, Inc. 1997)

- Manned and Unmanned Aerial Platform Operations on the Digitized Battlefield (MUM II) Concept Experimentation Program (CEP) (1998)

- Congressional Budget Office Paper Titled: Illustrative Options for DOD's UAV Programs (1998)

- Apache – Hunter Quick Reaction Contingency Program (1999)

- UAV Employment in Kosovo, Lesson Learned - U.S. Army (1999)

- Army After Next (AAN) Manned And Unmanned Teaming Control (Reconnaissance and Lethal UAV) Advanced Concepts And Technology II (ACT II) Program (1999-00)

- Manned and Unmanned Aerial Platform Operations on the Digitized Battlefield (MUM III) Concept Experimentation Program (CEP) (1999-00)

- Apache Video and Image Transmission System (AVITS) (1999-00)

- Airborne Manned/Unmanned System (AMUST) Program (1999-00)

- Manned and Unmanned Aerial Platform Operations on the Digitized Battlefield (MUM IV) Concept Experimentation Program (CEP) (2001-02)

- 3/21/95 RAH 66 Acquisition Decision Memorandum (ADM)

- 7/27/98 OIPT Comanche Program Restructure

- 7/29/99 RAH 66 Comanche Analysis of Alternatives (AoA) Studies and Analysis Group (SAG) Meeting (29 Jun. 99)

- 9/99 Outline of Operational Concept for Comanche and UAV

- 10/18/99 RAH 66 Comanche AoA SAG Meeting (8 Nov. 99)

- 4/7/00 RAH 66 Acquisition Decision Memorandum (ADM)

Most recently, as the design of the Apache Block III moves forward, an experiment was conducted in the Risk and Cost Reduction System (RACRS) simulator to examine the workload placed on pilots as the Block III technology is integrated into flight operations (Hicks et al., 2008).

The TSMs findings are summarized in an executive summary below (avi, 2000):

> "The initial exploration of UAVs operating with air maneuver platforms/systems began with aviation's participation in the Joint Precision Strike Demonstration (JPSD) in 1992. A proposed Advanced Concept Technology Demonstration

(ACTD) Survivable Armed Reconnaissance on the Digitized Battlefield followed the JPSD effort with the intent of integrating Comanche and UAV as a "system of systems". This ACTD candidate was not able to acquire funding to go beyond the planning stage. In 1993 the Aviation Warfighting Center began to explore the possible synergy gained from integrating manned and unmanned capabilities in pursuit of a common objective. The results of this multi-year effort, along with a number of other studies/experiments, make up the information contained in the blue book.

The studies and experiments conducted by the Aviation Warfighting Center were able to explore each of the five levels of UAV control. The findings from these studies indicate that additional assistance from advanced technologies will be required; otherwise levels 4 and 5 controls exceed the capability of a two-man crew. The following are insights gained from our past efforts:

a. A definite war fighting synergy is gained when manned and unmanned systems combine to accomplish a common objective. One of the unique contributions of the UAV system in the reconnaissance environment is that of tactical surveillance. Prior to the manned and unmanned experiments a tactical surveillance capability was not available to integrate with Division/Corps aviation reconnaissance organizations. A tactical surveillance capability integrated with, and directly responsive to, the aviation reconnaissance organizations greatly enhance our current Division/Corps ground and air maneuver reconnaissance capability.

b. The integration of information (pilot-vehicle interface) within the cockpit from an off board sensor must be accomplished in a manner similar to the integration of information utilized from the on-board sensors. Without similar processes the crew rapidly becomes task loaded (saturated) and in

some cases can become disoriented.

c. UAV observation and surveillance capabilities are complementary to and not a replacement for manned air maneuver reconnaissance capabilities.

d. The presentation and understanding of information gained from sensors located in different spatial positions and different geographical areas on the battlefield will require further definition and exploration.

e. Virtual simulation tools, which replicate the manned and unmanned capabilities, must be enhanced. Greater virtual simulation resolution for visual sensor information (current and projected) is required to more effectively examine the degree to which manned and unmanned systems should be integrated in the conduct of tactical reconnaissance missions.

f. Advanced technology must be integrated into the manned and unmanned systems (ground and air) to assist the manned crew in command and control of the unmanned system. Continuation of Combat System Crew Associate (formerly Rotorcraft Pilots Associate), Apache Video and Image Transmission System (AVITS) and Airborne Manned and Unmanned System Technology (AMUST) programs are essential to help define and advance the technology necessary for crews to effectively implement UAV control levels 4 and 5.

g. The integration of manned and unmanned system concepts, as defined over the past eight years, identified five areas that require additional emphasis and analysis. First, what are the Tactics, Techniques and Procedures and advanced technology applications, which allow the unmanned system a reasonable survivability rate? Second, which UAV organization is best suited for conducting tactical reconnaissance operations integrated with air maneuver systems and where should that organization be assigned? Third, what is the operational significance of a fixed wing UAV versus a Vertical Take Off and Landing (VTOL) UAV operating with or assigned to an aviation brigade/battalion organization? Fourth, as a result of the experimentation conducted to date is there a strong case for the Army having both a close and short range tactical UAV? Fifth, what is the impact of Military Operations in Urban Terrain (MOUT) on the integration of manned and unmanned systems (ground and air) in particular UAVs and air maneuver systems?

h. Simulation cannot completely duplicate live exercises or experimentation. Live interaction between manned and unmanned platforms ground and air will be essential to capture real world lessons learned and to provide a complete definition of required capabilities. Shortly after the decision to cancel the Hunter Tactical UAV Program a number of the Hunter Systems were placed in storage. In order to conduct live experimentation and advance the concept of aerial manned and unmanned platform integration, a Hunter platoon or company should be fielded to a division aviation brigade for a period of two years. During this time period UAV and manned systems would operate together as a team and help the Army define the degree to which manned and unmanned systems should be integrated."

Most of these findings were used to recommend UAV requirements to the TSM for integration into the Army UAV program. The positive experience with the use of simulation has been an effective means to help develop requirements but has not been transferred into crew and unit training capabilities.

Thus in 1993 The Army established the need for this type of system (UAS, and manned levels of interoperability) and has been developing the system from 1997 to present. Currently, as the development and production of the Block III Apache moves forward, the cooperative engagements system is concurrently in four stages of its life cycle:

- design and development

- production

- deployment, and

- system operation

This presents significant additional strains on an already complex system.

3 Technical Approach

The approach consists of three integrated efforts:

1. Experimentation with rated AH-64D helicopter pilots in the Risk Assessment Cost Reduction Simulator (RACRS) to determine the value and change in crew workload due to Video from Unmanned air systems for Interoperability Teaming Level II (VUIT-2), a system currently being installed in Block II Apache Aircraft.

2. Experimentation using lower resolution software, Virtual Battle Station 2 (VBS2), to provide insight as to whether this type of environment can represent and validate experimentation conducted in a much higher resolution and more expensive environment such as the RACRS. Through subjective and objective measures this experiment was designed to identify whether there are significant differences in a pilots performance, workload, and situational awareness between level I and level II interoperability with a UAS.

3. Using fundamental systems analysis techniques such as stakeholder and functional analysis combined with Human Factors and Accident Classification and risk management techniques develop a prioritized list of recommended controls to reduce the risk of mission failure during cooperative engagements between manned and unmanned aircraft systems.

In coordination with Army Research Labs a separate technical report, describing the method and results of the VUIT-2 experiment, was completed (Hicks et al.,

Fig. 7: RACRS simulator.

2008). Likewise an article has been written describing experimentation using VBS2 (Feliciano and Sperling, 2008). The results of these experiments will be summarized in this report.

4 Level 2 (VUIT-2) Simulation Workload Assessment

The West Point Operations Research Center worked with the Army Research Lab Human Research Engineering Directorate to conduct a simulation experiment to measure the cognitive workload on Apache helicopter crews during cooperative engagements using the VUIT-2 system.

The simulation consisted of operational missions conducted by Apache crews in the Apache Risk and Cost Reduction System (RACRS) simulator. The RACRS Cockpit consists of a high-fidelity Apache cockpit with aircraft flight controls. The simulator was modified to represent the UAS Level II functionality to the maximum extent practicable given the maturity of the Apache Block II design and limitations of the RACRS simulator. Four crews consisting of aviators of varying levels of experience participated in the simulation. After completion of training in the RACRS, each crew completed two missions in the simulator.

The operational scenario in the simulator replicated Southwest Asia geographical features and threats.

During the simulation, crew actions within the cockpit were recorded for post-test analysis. Video recordings of each crew station and all displays were kept as a permanent record. Log files recorded all button and switch activations as well as recorded which MPD display was selected on each of the MPDs during the test. An eye tracker system was installed in the CPG cockpit to record that crew member's visual gaze and dwell times. This system provided highly detailed information on the visual orientation of the test subject. After each simulated mission, the crew members were subjected to a detailed interview and completed a questionnaire battery. The information gathered from all of these sources provided a full picture of crew workload during the mission.

4.1   Crew Workload

Pilots reported that they typically experienced tolerable workload when performing missions while controlling the UAS. They reported that the workload they experienced was comparable to workload they experience during 'non-UAS' missions (TADS and/or FCR only). They commented that having to interact with an additional sensor (UAS sensor) increased their overall task workload, but the SA provided by the UAS sensor decreased the workload required to detect and engage targets and decreased overall target engagement timelines. Subject matter experts (SMEs) reported that the pilots typically experienced tolerable workload when controlling the UAS during missions, but had reduced spare workload capacity. The workload ratings provided by the pilots and SMEs were lower than the Objective and Threshold workload ratings requirements listed in the Apache Block III capability development document (Table 1).

4.2   Crew Situation Awareness

Pilots typically experienced moderate levels of SA during missions. They reported that they had high levels of SA of most of the battlefield elements (e.g., threat location) during the missions. However, there were several instances when they flew near the targets and fired missiles outside of the aircraft/UAS constraints. This was likely caused by the lack of extensive training and experience with the UAS and the need for improved cueing symbology to help pilots understand where their aircraft and the UAS are located in reference to the targets. The pilots stated that they had higher SA during VUIT-2 missions (vs. non-UAS missions) mostly because of the 'God's Eye' view that the UAS sensor video provided during missions. The UAS sensor video also gave the pilots good SA earlier in the mission (vs. non-UAS missions) because they often received the video prior to (or just after) take-off of their aircraft. The SMEs reported that the aircrews typically had adequate levels of SA.

4.3   Crew Coordination

The majority of pilots reported that the required level of crew coordination was higher during UAS missions than comparable non-UAS missions. They commented that having to manage an extra sensor increased their workload and required them to interact more with the CPG. The CPGs were split on whether having to manage an extra sensor increased the required level of crew coordination. The SMEs rated aircrew coordination during most missions as 'Good' or 'Average'.

4.4   UAS-Crew Station Interface

The CPGs were generally indifferent in their ratings of the UAS-Crew Station Interface (UCI). They reported that they were able to appropriately operate the switches and keypad to accomplish UAS mission tasks, although the current configuration was not considered the most efficient method. Pilots commented that the number of switch actuations per mission was not excessive, felt that the overall design of the UCI somewhat hindered them from interacting with the UAS in a timely manner, and reported that the UCI contributed to some high workload during data entry procedures and symbology interpretation. In some instances, the buttons were considered too

CDD Bedford Workload Rating Requirements	Pilot Bedford Workload Ratings for VUIT-2 Missions	SME Bedford Workload Ratings for VUIT-2 Missions
Objective Req. - 5.0	Pilot - 2.6	Pilot - 2.5
Threshold Req - 6.0	Co-Pilot/Gunner - 3.3	Co-Pilot/Gunner - 3.9

Tab. 1: Pilot workload requirements and ratings.

small to manipulate quickly and remembering their appropriate functions was difficult. The functionality of the keypad also caused an increase in time and workload during some missions. All of the pilots reported that the symbology presented was difficult to understand.

The pilots recommended that several enhancements be made to improve the UAS crew station interface, and overall operation. The pilots commented that with several enhancements and more experience using the system, most of the increased workload and decreased efficiency could be improved. Following are the key improvements that the pilots recommended should be made:

1. The symbology was very hard to see on our MPD. The icons represented around 800 meters on the map scale, which we used. It made it hard to tell where everything was really at. You could not see the symbology which tells which way it was flying or looking. Recommend changing the symbology and color to indicate appropriate flight information and line of sight for the UAS.

2. Not having a back arrow or a dedicated "enter" button on the VIP slows down our ability to quickly input the desired information. The buttons are too small for fast operation. There needs to be more streamlined setup like a computer keyboard. "Just use the KU" keyboard unit in the aircraft now.

4.5   VUIT-2 Recommendations

The following recommendations are made to enhance the overall effectiveness and suitability of the UAS VUIT-2 integration into the AH-64D:

1. Address and incorporate the recommended improvements (as appropriate) provided by the pilots, TRADOC Capability Managers Office, and Aviation Technical Test Center. Place emphasis on the key improvements listed in the experiment's technical report (Hicks et al., 2008).

2. Utilize the Crew Station Working Group to address and incorporate the recommended improvements.

3. Upgrade the RACRS simulator to make it representative of the AH-64D Block 3 design to enhance future simulations.

4. Continue using the RACRS to help train pilots, refine the UCI and techniques, tactics, and procedures for the Block 2 UAS integration (VUIT-2).

5. Maximize the amount of pilot training for future UAS evaluations.

6. Use the same data collection methodology (e.g., Bedford (Roscoe and Ellis, 1990), SART (Taylor, 1989)) during future simulations and tests for Apache VUIT-2 teaming. Standardizing the data collection methodology will help identify changes that work (e.g., changes that reduce workload), identify areas that still need more work, and help drive continuous incremental improvements.

5   Levels of Interoperability Low-Resolution Experiment

The RACRS simulation used high-end simulation technology. However, the experiment was expensive with respect to dollars spent and man-hours

(Sperling and Hicks, 2008). To help the Army in its research of cooperative engagements between a UAS and a manned aircraft, a similar experiment was conducted using undergraduate students (West Point Cadets) in a lower resolution environment (Feliciano and Sperling, 2008). During the experiment cadets were asked to react and respond to different situations in a helicopter simulation combat scenario; their performance, workload, and situational awareness were recorded after each scenario.

This research focuses on the differences between level I and level II interoperability. The experiment was designed for execution in the combat simulation lab of the Department of Systems Engineering at the United States Military Academy. The software used was Virtual Battlespace 2 (VBS2™). The results of this project will help determine whether a lower resolution and less expensive environment can validate experimental results obtained using a much higher resolution and more expensive environment such as the RACRS. Through subjective and objective measures this experiment was designed to identify whether there are significant differences in a pilots performance, workload, and situational awareness between level I and level II interoperability between a manned aircraft and a UAS. Figure 8 represents the deliberate attack mission used for this experiment.

Level I: Subjects conducted a combat helicopter simulation, from a single computer screen, with the basic Operations Order (OPORD). They were given verbal reports of UAS reconnaissance. Performance measures, workload of tasks, and situational awareness of battlefield elements were recorded.

Level II: Subjects conducted a combat helicopter simulation, from a single computer screen, with the basic OPORD. They were given verbal reports of UAS reconnaissance and a visual system providing a real-time payload video. The researcher used a computer nearby and provided subject with verbal and visual intelligence from a computer screen (See Figure 9). Performance measures, workload of tasks, and situational awareness of battlefield elements were recorded.

The low resolution experiment using Virtual Battlespace 2 (VBS2™) mirrored the VUIT-2 experiment in tactical scenario and metrics of performance, workload and situational awareness. The results indicated that when the subjects had access to live video feed from the UAS:

- Performance generally stayed constant between conditions, but in one case increased; this was displayed by a statistically significant decrease in the number of vehicles the subjects did not engage throughout the scenarios.

- Workload decreased during a number of phases of the scenarios; this was shown by a decrease in the Bedford workload scale during the following phases of each operation:

  - Target detection
  - Identification of allied and threat equipment
  - Actions on contact, and
  - Movement to contact

- Situational awareness (SA) generally stayed constant between conditions. But in two cases SA increased; this was shown by a statistically significant increase in SA in two phases of the operation: Location of enemy units, and location of non-combatants.

These results are consistent with the findings of the VUIT-2 experiment. These results indicate that experimentation using low resolution simulation can replicate that of a high resolution experiment, such as the RACRS simulation, yet be much more cost effective. This finding could also be transferred to the training domain.

6   Operational Risk Analysis

The system of systems being investigated, cooperative engagements, is currently operating in four stages of its lifecycle. This introduces additional risk
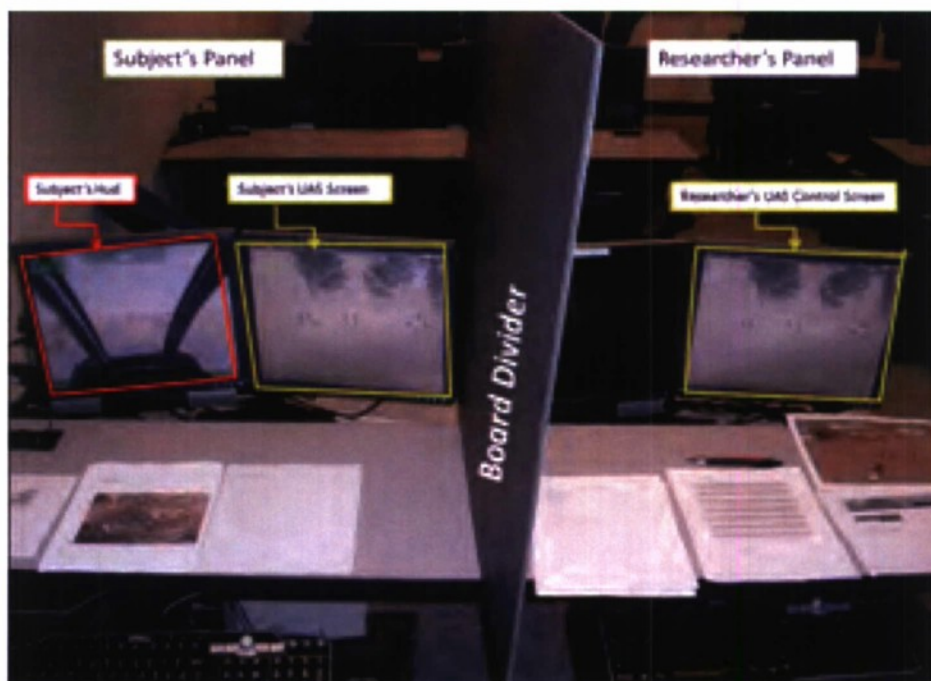
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Fig. 8: Deliberate attack map in VBS2™.

Fig. 9: Low-resolution experimental setup.

into an already complex system. Generally, the risk that is addressed in this effort is operational risk: one of the least quantified and less understood. Operational risk addresses the likelihood and severity of consequences during the operational stage of the system life cycle (Parnell et al., 2008). This research specifically considers operational risk as the risk to the success of a cooperative engagement mission between a manned and unmanned system. The goal of this portion of the research was to develop a list of operational risk mitigation controls and present them to the client in a prioritized manner based on the difficulty of implementation of the control versus the reduction in risk.

6.1   Method

A systematic and thorough risk assessment was necessary to identify as many risks to the system as possible. Complete risk assessment, such as required for this research, consists of these seven parts:

- Identification of the risk that is to be analyzed and potentially controlled.

- A qualitative description of the risk: why it might happen, events that would make it more or less likely to occur or may increase or decrease the subsequent impact should the event occur, and possible actions to take that might reduce the risk effectively.

- A semi-quantitative or quantitative assessment of the risk

- Development of risk management options that are available.

- Selection of the most effective and efficient risk management options

- Implementing the approved risk management plan.

- Communicating the plan and its basis to all relevant stakeholders (Parnell et al., 2008).

Fig. 11: LTC Sperling interviews UAS operators in Iraq.

The means by which this risk assessment was conducted was through the employment of various fundamental and advanced systems analysis techniques (Figure 10).

- Stakeholder analysis

- Functional hierarchy development

- Human Factors Analysis and Classification System (HFACS) analysis

  - Identification of operational risk events

- Determination of Risk of each event

  - Probability

  - Severity

- Development of controls across DOTMLPF
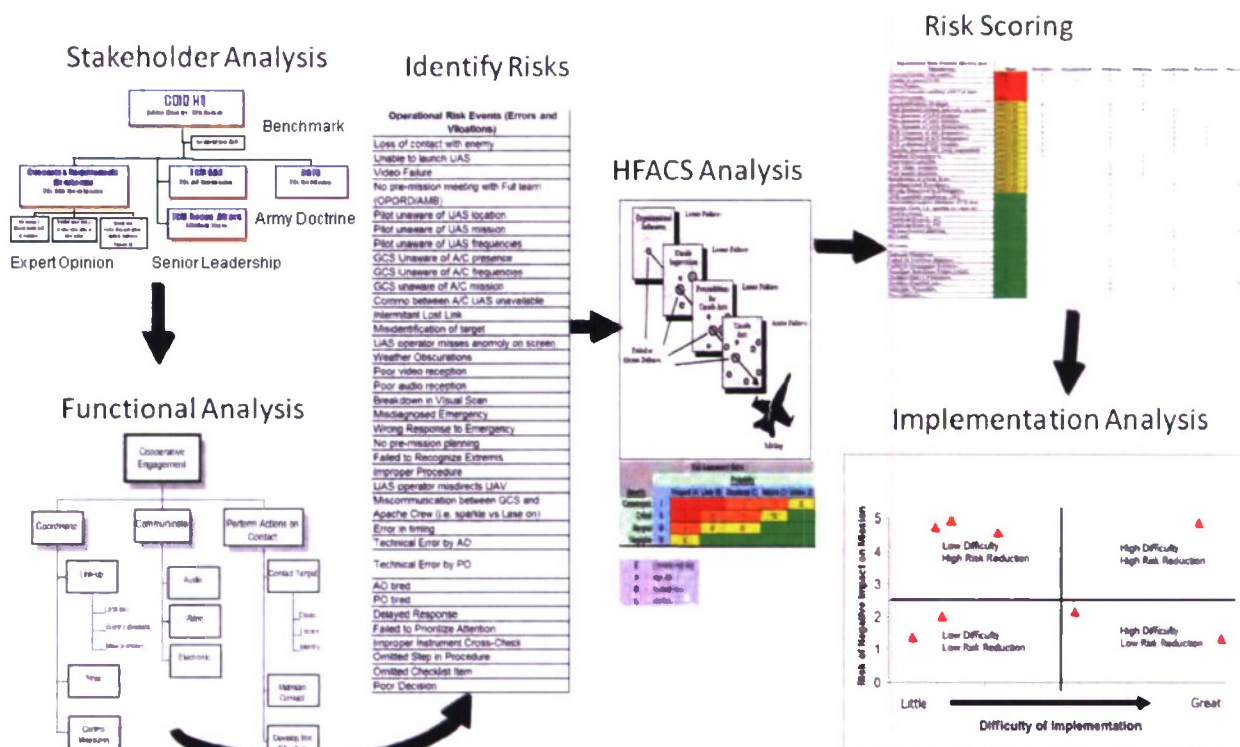
- Scoring of controls

- Sensitivity analysis

Fig. 10: Operational risk assessment methodology.

6.2 Stakeholder Analysis

Stakeholder analysis initiated this effort, but never truly ended. Stakeholders comprise the set of individuals and organizations that have a vested interest in the problem and its solution (Sage and Armstrong, 2000). A thorough stakeholder analysis was essential to obtain a clear problem definition and was critical to the success of this project. Various stakeholder opinions were elicited through interviews, focus groups, surveys and observation throughout this process at different levels within the system and for different purposes. Initially high level management was assessed in order to establish the width and breadth of the problem. Throughout the rest of the process mid-level management and user level stakeholders were the primary focus to establish functions of the system, operational risk events, their associated probabilities and severities, and possible controls along with their associated cost and benefit. The most valuable assessments were conducted in Afghanistan and Iraq where the leadership of two Combat Aviation Brigades, five Brigade Combat Teams, two Task Forces, and 11 of the 22 Shadow platoons were assessed (Figure 12).

The problem definition matrix shown in Figure 13 was used to organize some of the stakeholders' primary concerns by environmental factors surrounding and embedded in the system. This method can lead the analyst in a more fruitful direction when assessing a new stakeholders. Furthermore, it helps establish relationships between stakeholders.

6.3 Functional Analysis

Once the stakeholder analysis and problem definition framework were complete, a functional analysis was used to organize into a hierarchy the functions that must occur on the battlefield for a successful cooperative engagement to take place. These functions all fall into one of three categories - coordinate, communicate, and perform actions on contact. It is important to note that for successful cooperative engagements, the functions are not confined to only UAS systems

or helicopters. They must be performed by the entire ground-air team to include units on the ground and the command and control nodes responsible for them (Figure 14).

6.4 Human Factors Analysis and Classification System

Considering the functions identified in the functional analysis, the stakeholders were asked about the things that could possibly go wrong in the conduct of cooperative engagements. There were considered potential risks to successful completion of the mission - operational risks. These risks were elicited from stakeholders during interview sessions, and they were further refined by the analysis team once the list had been compiled. The Human Factors Analysis and Classification System (HFACS), originally conceived as a framework for safety assessments, was used to elicit risks (Shappell and Wiegman, 2000). It includes risk identification in the following areas:

- Organizational factors

  - Inappropriate organizational structure/manning

  - Inadequate promotion policies

  - Inappropriate culture

- Inadequate supervision

  - Deficient training program

  - Failure to provide operational doctrine

  - Failure to correct inappropriate behavior

  - Improper work tempo (risk without benefit)

- Preconditions

  - Poor team work/team resource management

  - Loss of situational awareness

  - Improper briefing before an operation

Decision Authority:
Capability
Developments
Integration Directorate

CDID HQ
Acting Director: Ellis Golson

Integration Cell

Concepts & Requirements Directorate
COL Rick Stockhausen

TCM UAS
COL Jeff Kappenman

DOTD
COL Rich Knapp

Concept Development Division

Requirements Determination Division

Aviation Experimentation and Analysis Element

TCM Recon Attack
COL Mark Hayes

Client:	Users/Consumers:	OEF:	OIF:
PM Apache	1-101 Attack Bn	173rd Airborne TF Bayonet	2/25th BCT
PM UAS	3-159th Attack BN,	2-17 CAV TF Outfront	3/4th BCT
Apache Block III PM	UAS Training Bn	101st CAB	2/3rd BCT
Apache Block Vuit-2 PM	DES		4/3rd BCT
	Shadow PM		12th CAB

Fig. 12: Cooperative engagement stakeholders.

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| Problem Definition Matrix		Decision Maker/Stakeholder				
		Decision Makers: Capability Developments Integration Directorate	Client: PM Apache/UAS	Owner: US Army	User: UAS /AH64-D crews	Consumer: Army maneuver units
Environmental Factors	**Cultural**					
	Economic	Acquisition Cost	Acquisition Cost	Total Cost		Operating/ Support Cost
	Emotional	Future of Manned Attack Aviation	Block III Apache sunk costs	Aviation Airspace Concerns	Aviation Airspace Concerns/Tasking Authority	
	Natural Environment	Doctrinal Changes	Identify/Meet changing requirements	Weather, Electronic Interference, Urban Canyon	Weather, Electronic Interference, Urban Coverage, Operational Limitations, Airspace Coordination process and proceedures	Weather, Electronic Interference, Urban Coverage, Airspace Coordination, process and proceedures
	Historical	Past Programs/Stovepipe organizations	Similar Past Programs(FCS)	Past experience with similar operations (fire support, CAS)	Past experiance with similar operations (fire support, CAS)	Past experience with similar operations (fire support, CAS)
	Legal	Acquisition Regulations/ Laws, FAA	Acquisition Regulations/ Laws	UCMJ, Geneva Conventions, ROE	Operational Limitations, Weapons' ROE (record engagements) Target ID	Operational Limitations, ROE
	Moral/Ethical	Acquisition Regulations/ Laws, FAA	Acquisition Regulations/ Laws	ROE	ROE	ROE
	Organizational	Number of Systems, Organizational Control of Systems	Number of Systems	Unit Organization, Number of Different Systems	Training, Operation (BHO, THO, etc.) and coordination (freqs, AO, etc.)	Education of capabilities, Coordination of assets
	Political			Media Attention		
	Social					
	Technological	Provides Capabilities beyond Doctrine	Development	Provides Capabilities beyond Doctrine	Workload, Levels of Interoperability, process and procedures	Capabilities, process and procedures
	Security	Informational, Physical	Informational, Physical	Informational, Physical	Informational, Physical	Informational, Physical

Fig. 13: Problem definition matrix.
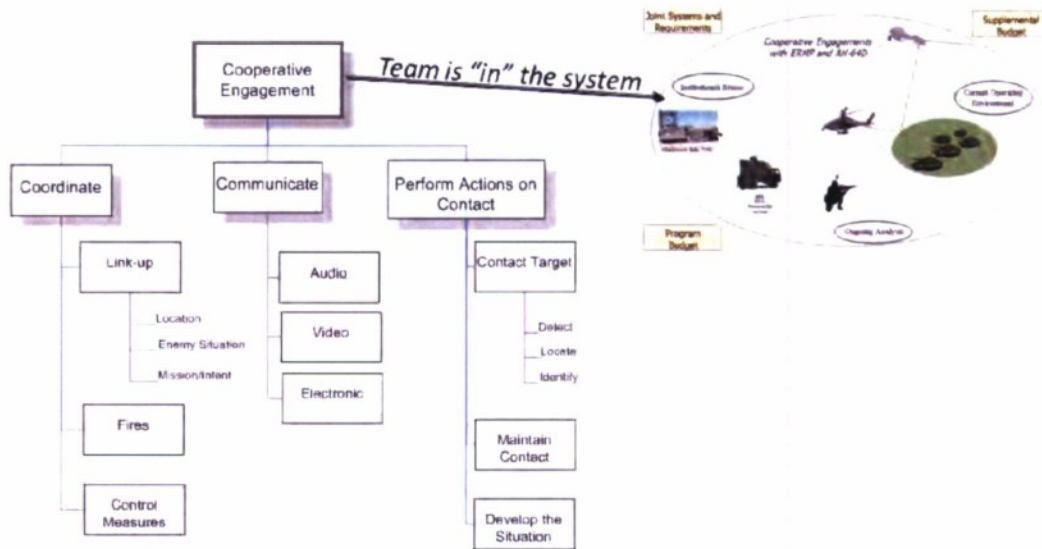
Fig. 14: Functional analysis for cooperative engagements.

- Actions during the operation

    - Misidentification of target
    - Did not communicate all needed information
    - Failed to recognize extremes

By the HCACS framework, mission failure can be caused by a risk factor in any one of the categories. However, failure often stems from an unfortunate alignment of multiple risks, cutting across all of the categories. In a safety framework, accidents often have multiple related causes. In an operational framework, mission failure often stems from multiple deficiencies. This analysis seeks to identify as many of these factors as possible so that mitigating actions may be taken to reduce or eliminate as many of these risks as possible.

6.5 Risk Scoring

All risks are not equal. Some are more serious than others. The US Army has developed a two-dimensional risk assessment framework that categorizes risks based on both probability ans severity (Department of the Army, 1998) as illustrated in Figure 15. The severity of the risk is grouped into the following categories:

CATASTROPHIC (I) - Loss of ability to accomplish the mission or mission failure. Death or permanent total disability (accident risk). Loss of major or mission-critical system or equipment. Major property (facility) damage. Severe environmental damage. Mission-critical security failure. Unacceptable collateral damage.

CRITICAL (II) - Significantly (severely) degraded mission capability or unit readiness. Permanent partial disability, temporary total disability exceeding 3 months time (accident risk). Extensive (major) damage to equipment or systems. Significant damage to property or the environment. Security failure. Significant collateral damage.

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Fig. 15: Risk assessment matrix.

MARGINAL (III) - Degraded mission capability or unit readiness. Minor damage to equipment or systems, property, or the environment. Lost day due to injury or illness not exceeding 3 months (accident risk). Minor damage to property or the environment.

NEGLIGIBLE (IV) - Little or no adverse impact on mission capability. First aid or minor medical treatment (accident risk). Slight equipment or system damage, but fully functional and serviceable. Little or no property or environmental damage.

In addition, the probability of the risk factor is taken into account:

FREQUENT (A) Occurs very often, continuously experienced

LIKELY (B) Occurs several times

OCCASIONAL (C) Occurs sporadically

SELDOM (D) Remotely possible; could occur at some time

UNLIKELY (E) Can assume will not occur, but not impossible

Figure 16 shows the results of risk identification and scoring for cooperative engagements.

6.6 Controls

Once the risks had been identified and scored, the analysis team worked with the stakeholders to brainstorm a list of controls - those actions that could be taken to eliminate or mitigate the identified risks. These controls span doctrine, organization, training, materiel, logistics, personnel, and facilities (DOTMLPF). Those controls are listed in Table 2. Each control mechanism was scored on a two-dimensional scale. The first factor is a risk reduction score. This score was a weighted sum of the control's ability to mitigate each risk factor where the weight is based on the risk category. The second score is a subjective ranking of the difficulty of implementation for the controls. These results are plotted in Figure 17 where the factors circled in green represent low-hanging fruit. These controls can be implemented relatively easily with a significant reduction in overall risk. The controls in yellow represent a second tier where implementation involves significant effort, and the overall risk reduction is not as great. Finally, those factors circled in red represent controls that are very difficult to implement with only a marginal risk reduction. Implementation of these is not recommended.

6.7 Results.

Based on the scoring of controls, the results of this study fall into three categories. Recommendations should be strongly considered for implementation. Considerations should be further analyzed for possible implementation. Finally, honorable mentions should be assessed in the context of other information, beyond the scope of this study, before considering action.

6.7.1 Recommendations

Deployable Virtual Training Environment (DVTE) for Training (Control #10). Develop a simulation capability for collective training in cooperative engagements similar to the Marines' DVTE.

Operational Risk Events (Errors and Violations)	Mean Probability	Variance Probability	Max Probability	Average Probability	Max Probability	Severity	Max Risk
Loss of contact with enemy	2.3	0.678	2.978	SELDOM	OCCASIONAL	CATASTROPHIC	HIGH
Unable to launch UAS	2.5	0.278	2.778	OCCASIONAL	OCCASIONAL	CRITICAL	HIGH
Video Failure	2.7	1.567	4.267	OCCASIONAL	LIKELY	CRITICAL	HIGH
No pre-mission meeting with Full team (OPORD/AMB)	4.8	0.178	4.978	FREQUENT	FREQUENT	MARGINAL	HIGH
Pilot unaware of UAS location	3.9	1.878	5.778	LIKELY	FREQUENT	MARGINAL	HIGH
Pilot unaware of UAS mission	3.9	1.878	5.778	LIKELY	FREQUENT	MARGINAL	HIGH
Pilot unaware of UAS frequencies	3.9	1.878	5.778	LIKELY	FREQUENT	MARGINAL	HIGH
GCS Unaware of A/C presence	3.9	1.878	5.778	LIKELY	FREQUENT	MARGINAL	HIGH
GCS Unaware of A/C frequencies	4.1	2.100	6.200	LIKELY	FREQUENT	MARGINAL	HIGH
GCS unaware of A/C mission	4.1	2.100	6.200	LIKELY	FREQUENT	MARGINAL	HIGH
Commo between A/C UAS unavailable	4.2	1.956	6.156	LIKELY	FREQUENT	MARGINAL	HIGH
Intermitant Lost Link	3.7	1.344	5.044	LIKELY	FREQUENT	MARGINAL	HIGH
Misidentification of target	3.3	0.233	3.533	OCCASIONAL	LIKELY	MARGINAL	MEDIUM
UAS operator misses anomaly on screen	2.6	0.711	3.311	OCCASIONAL	OCCASIONAL	MARGINAL	MEDIUM
Weather Obscurations	2.8	1.067	3.867	OCCASIONAL	LIKELY	MARGINAL	MEDIUM
Poor video reception	3.4	0.711	4.111	OCCASIONAL	LIKELY	MARGINAL	MEDIUM
Poor audio reception	2.5	0.944	3.444	OCCASIONAL	OCCASIONAL	MARGINAL	MEDIUM
Breakdown in Visual Scan	3	1.333	4.333	OCCASIONAL	LIKELY	MARGINAL	MEDIUM
Misdiagnosed Emergency	1.9	0.544	2.444	SELDOM	SELDOM	CRITICAL	MEDIUM
Wrong Response to Emergency	1.7	0.678	2.378	SELDOM	SELDOM	CRITICAL	MEDIUM
No pre-mission planning	2.1	2.100	4.200	SELDOM	LIKELY	MARGINAL	MEDIUM
Failed to Recognize Extremis	1.4	0.267	1.667	UNLIKELY	SELDOM	CRITICAL	MEDIUM
Improper Procedure	2.2	1.067	3.267	SELDOM	OCCASIONAL	MARGINAL	MEDIUM
UAS operator misdirects UAV	1.6	0.267	1.867	SELDOM	SELDOM	NEGLIGIBLE	MEDIUM
Miscommunication between GCS and Apache Crew (i.e. sparkle vs Lase on)	1.9	0.322	2.222	SELDOM	SELDOM	MARGINAL	LOW
Error in timing	1.7	0.233	1.933	SELDOM	SELDOM	NEGLIGIBLE	LOW
Technical Error by AO	2.9	0.544	3.444	OCCASIONAL	OCCASIONAL	NEGLIGIBLE	LOW
Technical Error by PO	2.4	0.489	2.889	SELDOM	OCCASIONAL	NEGLIGIBLE	LOW
AO tired	2	0.444	2.444	SELDOM	SELDOM	MARGINAL	LOW
PO tired	2	0.444	2.444	SELDOM	SELDOM	MARGINAL	LOW
Delayed Response	2.1	0.322	2.422	SELDOM	SELDOM	NEGLIGIBLE	LOW
Failed to Prioritize Attention	2.2	0.178	2.378	SELDOM	SELDOM	NEGLIGIBLE	LOW
Improper Instrument Cross-Check	1.8	0.178	1.978	SELDOM	SELDOM	MARGINAL	LOW
Omitted Step in Procedure	1.6	0.711	2.311	SELDOM	SELDOM	MARGINAL	LOW
Omitted Checklist Item	1.7	0.678	2.378	SELDOM	SELDOM	MARGINAL	LOW
Poor Decision	1.7	0.678	2.378	SELDOM	SELDOM	MARGINAL	LOW

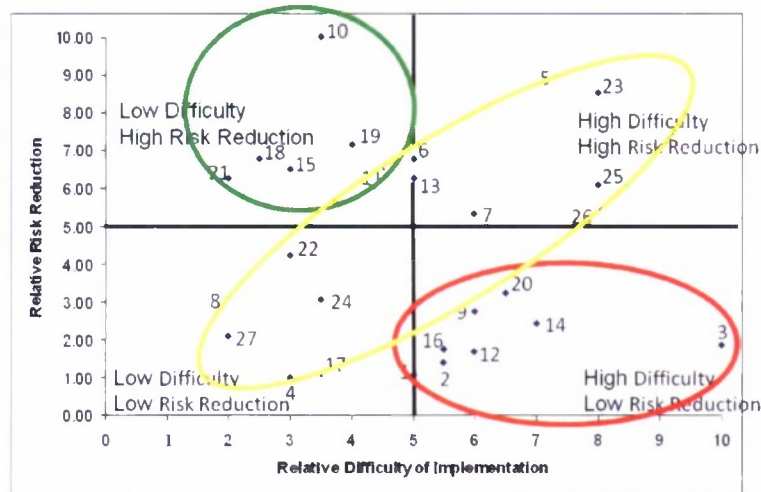Fig. 16: Risk factors for successful cooperative engagements.

Fig. 17: Scoring of the DOTMLPF controls. See Table 2 for a listing of controls plotted here.

This is a laptop-based system designed to be light and deployable so that Marines can do small unit combined arms collective training in austere environments at the unit level (Office of Naval Research, 2007). It is composed of existing commercial and government-owned technology and is hosted on a self-contained network of easily configurable laptop computers. It contains an emulation of a tactical communications network and provides a state-of-the-art after action review capability. This capability would allow Apache pilots and UAS operators to work together to develop standard operating procedures (SOPs) and coordination mechanisms for cooperative engagements. This training capability would address many of the risk factors identified in this study, and, because a Marine system of similar capabilities already exists, adaptation to an Army capability would not be as difficult and building a system from scratch. The West Point Operations Research Center will conduct a follow-on study in order to further develop the requirements and potential approaches to achieving this capability.

proaches to achieving this capability.

Standards and Leadership (Control #21). Assessments from the stakeholder analysis and functional analysis process showed that some UAS units operated without clear standards or a clear mandate to follow those standards using pre-flight and pre-operations checklists and other aids. This is a problem that could be easily fixed by the leadership of UAS units, and it would have a significant impact on successful cooperative engagements in theater.

Leader's Guide (Control #18). Develop a leader's guide for cooperative engagements. This guide would provide essential information about expectations that a commander may have regarding manned/unmanned cooperative engagements in the operational environment. This handbook is intended as a quick-reference for military commanders at brigade-level and below to employ this unique asset. The West Point Operations Research Center will conduct a follow-on study to draft an initial version of this leader's guide.

Mobile Training Teams (MTTs) (Control #19). Employ Mobile Training Teams to brief in-theater leadership on capabilities and procedures. The target audience is brigade and battalion commanders and staff. These teams would also be able to work with units in their pre-deployment training cycle.

Organize UAS under the combat aviation brigade (CAB) (Control #5). Organize UAS under general support aviation brigade (GSAB) for staff, safety, standardization, and maintenance support. UAS would still task organize and operate as the tactical situation dictates. For example, the ground control station would still be able to co-locate with the brigade combat team, but the launch teams could be consolidated at the GSAB. This reduces the number of single-point failures and prevents situations where platoons operate alone with only one or two maintainers. During stakeholder interviews, the commander of 4-3 BCT was, "...not in favor of consolidation at first, but I have seen no negative impact on mission support, what we have gained is economy of force." According to his operations officer, "We have actually had extra support when needed."

6.7.2 Considerations

Decision Support Tools for GCS Operators (Control #15). Develop decision support and computer aided tools to improve the efficiency and effectiveness of ground control station crews. Currently planned improvements will allow the pilot to operate more than one aircraft. However, it would be very difficult for the payload operator to monitor more than one sensor. This is where some automation would be most useful.

BCT Level Simulation Training (Control #11). Expand the simulation concept addressed with DVTE (Control #10) to include brigade and battalion training for the staffs and commanders that must plan, allocate, and execute handoff for cooperative engagements. This training capability would have to be integrated with simulation tools and processes currently used for BCT training. Virtual situational training exercises at the BCT level would

Controls	
1	Joint Pub
2	IFR
3	Natl Airspace
4	Doctrine Developers
5	UAS under CAB
6	AVN WO
7	BAEs
8	UAS mix CAB/Div
9	Army Control
10	DVTE
11	BCT Sim
12	Schoolhouse
13	VUIT-2 101st
14	Arming UAS
15	Decision Support Tool
16	Platoon/CO OSRVTs
17	VUIT-2 digital recorder
18	Leader's Guide
19	MTTs
20	Pre-Command Course
21	Standards-leadership
22	CRC
23	ERMP Pax before system
24	AMP system
25	29 Pax Platoon
26	Qualified Operators
27	ASI on USR

Tab. 2: List of DOTMLPF controls.

Fig. 18: BCT level TOC where cooperative engagements are often coordinated.

address the training gap for staffs that must coordinate and execute these missions. The follow-on study by the West Point Operations Research Center will address some of the requirements for this capability.

Aviation Warrant Officer (Control #6). Assign an aviation warrant officer to UAS platoons as a technical warrant. Initial scrubs of accident data show that this would reduce the risk of accidents and improve the number of flying hours for UAS. Observations during stakeholder analysis in Iraq and Afghanistan showed higher standards and better attention to detail when aviation warrant officers were employed in this role.

Install VUIT-2 on 101st Aircraft (Control #13). In order to better equip units for cooperative engagements, install VUIT-2 equipment on the aircraft from the 101st Combat Aviation Brigade currently in Afghanistan. These aircraft would remain in theater as new units fell in on this equipment to continue operations.

6.7.3 Honorable Mention

Combat Readiness Center Investigations (Control #22). Insist on Combat Readiness Center (CRC) investigations of UAS accidents.

ASI on USR (Control #27). Insist on reporting UAS Additional Skill Identifiers (ASI) on the Unit Status Report (USR).

Schoolhouse Education (Control #12). Improve UAS schoolhouse education with respect to weather effects on UAS flight and maintenance procedures, records, and tracking.

Personnel (Control #25). Man the UAS platoon at 29 personnel. The number of soldiers is more important to successful UAS operations than the number of systems.

Organization of UAS in the Army (Control #9). Retain UAS organizations in the US Army rather than outsourcing this capability to the US Air Force. This allows UAS operators to better understand their role in the overall scheme of maneuver and commander's intent. They will be able to build habitual relationships with ground maneuver units and manned aviation assets and enable greater opportunities for cooperative engagement and manned/unmanned teaming.

7 Conclusions

The integration of Apache attack helicopters with UAS video is a system of systems integration that provides a valuable capability to commanders charged with counter-insurgency operations in Iraq and Afghanistan. This study has looked into some of the complex challenges that occur within systems of systems engineering and provided valuable feedback to leaders across the aviation, unmanned systems, acquisition, and operations communities. It has addressed the concern of cognitive overload for Apache pilots who use the VUIT-2 system for cooperative engagements. Conclusions from two independent studies show a manageable cognitive load for both the pilot and co-pilot/gunner. They reported a reduced workload during target identification due to the overhead view provided by the UAS. In addition to the cognitive workload experiments, this study took a comprehensive look into all of the DOTMLPF factors associated with successful cooperative engagements.

This included a visit to UAS platoons and BCTs in Iraq and Afghanistan currently conducting these missions. After applying a risk management analysis framework to these factors, some clear recommendations have emerged. The Operations Research Center will conduct a follow-on study further investigating two of these recommendations. We will determine requirements and technical recommendations for the potential development of a virtual training capability for cooperative engagements that would allow UAS operators and pilots to work together in developing coordination measures and SOPs before deploying to theater. We will also develop a draft version of a leaders guide for cooperative engagements focused at leaders at brigade and below who employ these assets in support of operations.

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Nomenclature

A2C2S Army Airborne Command and Control System

AAN Army After Next

ACTD Advanced Concept Technology Demonstration

ADM Acquisition Decision Memorandum

AIU Aircraft Interface Units

AMUST Airborne Manned/Unmanned System

AoA Analysis of Alternatives

ASI Additional Skill Identifier

ATD Advanced Technology Demonstration

AVITS Apache Video and Image Transmission System

BCT Brigade Combat Team

BDA Battle Damage Assessment

CAB Combat Aviation Brigade

CDD Capability Development Document

CEP Concept Experimental Program

CPG Co-pilot/Gunner

CRC Combat Readiness Center

DoD Department of Defense

DOTMLPF Doctrine, Organization, Training, Materiel, Logistics, Personnel, and Facilities.

GCS Ground Control Station

ISR Intelligence, Surveillance, and Reconnaissance

JPSD Joint Precision Strike Demonstration

LCT Longbow Crew Trainer

MP Mission Processors

MTCDL Mini-Tactical Common Data Link

MUM Manned/Unmanned

OPORD Operations Order

PGCS Portable Ground Control Station

ROVER Remote Operations Video Enhanced Receiver

RVT Remote Video Terminal

SA Situation Awareness

SAG Studies and Analysis Group

SME Subject Matter Expert

SOP Standard Operating Procedure

TADS Target Acquisition Designation Sight

TCDL Tactical Common Data Link

TCM TRADOC Capabilities Manager

TRADOC Training and Doctrine Command

TSM TRADOC System Manager

TUAS Tactical Unmanned Aircraft System

UAS Unmanned Aircraft Systems

UCI User-Crew Station Interface

USR Unit Status Report

VBS2 Virtual Battlespace 2

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

This study outlines efforts to look into some of the considerations for integrating UAS video into the Apache cockpit in order to support cooperative engagements between UAS and attack helicopters. In these cooperative engagements, the UAS initially detects the target. A tactical operations center then does coordination with pre-planned or dynamically re-tasked aviation assets to move to the target area and engage the target. As the UAS hands off the target, the ability to view the UAS video inside the Apache cockpit supports a faster and more reliable target acquisition with greater situation awareness of the target area. This study addresses concerns about the cognitive workload this additional video places on the pilots. It also addresses some of the factors associated with overall success of cooperative engagements. This second portion of the study included a deployment into Iraq and Afghanistan to do detailed stakeholder analysis and functional analysis in order to better understand cooperative engagements and the potential challenges they pose for all elements of this systems of systems integration.

15. SUBJECT TERMS

Human factors engineering, System of Systems Engineering, Unmanned Aircraft Systems, Aviation

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